APPENDIX A, CASSINI RECORD OF DECISION

RECORD OF DECISION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Cassini Mission
Environmental Impact Statement (EIS)

A. The Cassini Mission

The Cassini mission is an international cooperative effort undertaken by NASA, the European Space Agency (ESA), and the Italian Space Agency (ASI) to explore the planet Saturn and its environment. Cassini is part of NASA's continuing program for exploration of the solar system, the goal of which is to understand its birth and evolution. The Cassini mission is planned to be launched from Cape Canaveral Air Station (CCAS) and will involve a 4-year tour of Saturn, its atmosphere, moons, rings, and magnetosphere by the Cassini spacecraft, which consists of the Orbiter and the detachable Huygens Probe. The Huygens Probe will be released from the Cassini Orbiter to descend by parachute through the atmosphere of Saturn's largest moon, Titan. During the descent, instruments on the Probe will directly sample the atmosphere and determine its composition. The Probe will also gather data on Titan's landscape. Upon completion of the Probe mission, the Orbiter will continue to make remote and in-situ measurements of Saturn and its environment. This information could provide significant insights into the formation of the solar system and the-conditions that led to life on Earth.

NASA will provide the Orbiter, the Earth-based communications and operations network, and two scientific instruments on the Huygens Probe. ESA will provide the Huygens Probe, and ASI will provide major elements of the Orbiter's communications equipment and elements of several science instruments.

The scientific and technological benefits expected from the Cassini mission are demonstrated by the long record of support not only by our Nation's scientific community, the Congress, and Executive Branch agencies, but also by the international science community and many European nations.

B. Introduction to the EIS

This EIS was developed to address all major elements of the Cassini mission. Formal scoping began in February 1991 and continued into April 1991. This scoping period was for the Outer Solar System Exploration Program, which included both the Comet Rendezvous Asteroid Flyby (CRAF) and Cassini missions. Thirty-three scoping comment letters were received. They dealt with: alternative power sources; risks and impacts from plutonium-238 (PU-238) in the Radioisotope Thermoelectric Generators (RTGs) ; accident probabilities and risk factors; mission alternatives; and NASA policy. In January 1992 the CRAF mission was canceled and by May 1992 Cassini was restructured; an information update to this effect was published in October 1992. The scoping comments were then used in developing a cassini-specific Draft EIS (DEIS).

The DEIS was made available to the public in October 1994. Fifty-one comment letters were received. These comments dealt with a range of issues, including: the use of plutonium in space; the status of solar technology for deep space missions; the properties of plutonium; the radiological consequence and risk analyses; effects on ground water near the launch site; and cumulative environmental impacts on stratospheric ozone.

The Final EIS was made available on July 21, 1995, and the waiting period expired on August 21, 1995. Ten comment letters were received. These letters raised no new issues, nor did they provide new information; six of the commentors reiterated issues they raised earlier for the DEIS.

Alternatives Considered

The alternatives addressed in the EIS were:

1. Completion of preparation for and implementation of the Cassini mission to Saturn, including its launch onboard a Titan IV (with either the Solid Rocket Motor Upgrade [SRMU] or the Solid Rocket Motor [SRM][1], and a Centaur upper stage) during the primary launch opportunity in October 1997, using a Venus-Venus-Earth-Jupiter Gravity Assist (VVEJGA) trajectory; a secondary opportunity in December 1997, using a Venus-Earth-Earth Gravity Assist (VEEGA) trajectory; or a backup opportunity in March 1999, using a VEEGA trajectory. The primary opportunity will enable gathering the full science return (i.e., data) desired to accomplish the mission science objectives. Achievement of the science objectives for the secondary and backup opportunities would essentially be the same as for the primary, but with reduced science return.

2. Completion of preparation for and implementation of the Cassini mission to Saturn involving dual Space Shuttle launches in early 1999, with on-orbit assembly of the spacecraft with its upper stage(s), followed by injection in March 1999 on a VEEGA trajectory. A backup opportunity, also a VEEGA, occurs in August 2000. This alternative, including both the primary and backup opportunities, would
obtain less science return than the Titan IV (SRMU)/Centaur 1997 primary opportunity.

3. Completion of preparation for and implementation of the Cassini mission to Saturn onboard a Titan IV (SRMU)/Centaur using a Venus-Venus-Venus Gravity Assist (VVVGA) trajectory in March 2001 or a VEEGA backup opportunity in May 2002. This alternative would require both increasing the propellant capacity of the Cassini spacecraft and completing development of a new, high-performance rocket engine. This alternative, including both the

[1] At the time of this Record of Decision, the SRM has become unavailable as an option.

primary and backup opportunities, would obtain less science return than the Titan IV (SRMU)/Centaur 1997 primary opportunity.

4. Adoption of the no-action alternative, resulting in termination of preparations for implementing the Cassini mission. This alternative would impede our Nation's Solar System Exploration Program, deprive the world of invaluable scientific discoveries, and disrupt internationally cooperative space activities for the benefit of all humankind.

Mission Components Evaluated

In addition to the basic engineering design of the spacecraft, the other key components associated with the Cassini mission are the launch vehicle, the interplanetary trajectory, and the power system for the spacecraft's electrical requirements. These must function together to satisfy the requirements of the mission.

Key components were evaluated in the EIS in terms of technical feasibility, ability to satisfy the science objectives of the mission, and potential for reducing the postulated environmental impacts associated with the October 1997 baseline mission design. To be considered technically feasible, a component must have been tested for space-flight applications or must be in the development stages on a timetable consistent with satisfying Cassini's science objectives. The requirement for components to satisfy the science objectives is essential because the mission must provide useful information in a timely manner.

The evaluation of mission components led to the following determinations: (1) the Titan IV (SRMU)/Centaur is the most capable U.S. launch system available and most closely matches this requirements of the Cassini mission; (2) the Cassini mission to Saturn requires planetary gravity-assist trajectories; and (3) the spacecraft requires the use of three mainly plutonium-238 dioxide-fueled ($^{238}PuO_2$) RTGs and up to 157 Radioisotope Heater Units (RHUs) to satisfy the mission electrical and thermal requirements. The total $^{238}PuO_2$ inventory will be around 400,000 curies at time of launch. NASA's Jet Propulsion Laboratory conducted an in-depth analysis of the available electrical power systems, including many different solar, battery, and long-life fuel cell power sources and hybrid systems to identify the most appropriate power source for the Cassini mission. None of-these were found to be technically feasible for Cassini. For example, a Cassini spacecraft equipped with the highest efficiency solar cells available would make the spacecraft too massive for launching to Saturn. The spectrum of available launch vehicles was also analyzed, and it was determined that there is no available launch vehicle which could avoid planetary gravity assist trajectories.

Environmental Consequences of the Alternatives

In considering the consequences of the alternatives, it was recognized that ordinarily the only direct or immediate environmental impacts would be associated with the normal launch of Cassini. The environmental impacts of normal Titan IV or Space Shuttle launches have been addressed in other National Environmental Policy Act (NEPA) documentation (e.g., the Titan IV Environmental Assessments [EAs]; Space

Shuttle, Kennedy Space Center, Galileo [Tier-2] and Ulysses [Tier-2] EISs), and have been updated in the Cassini EIS. These impacts have been deemed insufficient to preclude either Titan IV or Space Shuttle operations.

Consideration of launch and inadvertent reentry accidents involving radiological consequences was a principal focus of the Cassini EIS. The U.S. Department of Energy (DOE), a cooperating agency, provides the RTGs and RHUs. For the Cassini mission, DOE has prepared a preliminary risk analysis for accidents which are postulated as causing a release of plutonium dioxide fuel from the RTGs or RHUs. The EIS incorporates the results of DOE's preliminary risk analysis.

The analysis proceeded as follows:

a) NASA defined the launch vehicle representative (postulated) accident scenarios[2], and the environments (e.g. propellant fires and explosions, high speed fragments, reentry conditions, etc.) to which the RTGs and RHUs might be exposed in the event of an accident. NASA also provided the probabilities of occurrence of the accident scenarios.

b) Based on the similarity of the representative accident scenario environments to those arising from the accident scenarios analyzed for the 1990 Ulysses Final Safety Analysis Report (FSAR) supplemented with additional analyses, DOE estimated the response of the RTGs and RHUs to those environments. In this manner, DOE was able to determine if a given representative scenario could lead to a release of plutonium dioxide fuel and the potential amount of a release (i.e., a "source term").

C) For those cases where a release could possibly occur, DOE then estimated the dispersion, deposition, and health and environmental consequences along with the probability of occurrence given that the postulated release occurred.

The radiological consequence results are reported in the EIS in terms of "expectation" and "maximum" cases. The expectation case for a given representative accident scenario represents a probability-weighted average over conditions associated with the accident scenario under consideration, and uses the average source terms developed in the analysis. The maximum case for a given representative accident scenario represents a nominal upper limit without consideration of uncertainties[3] , based on the use of the maximum source terms. The maximum case corresponds to either the upper limit deemed credible for a given representative scenario based on consideration

[2] The Cassini EIS deals with a set of four credible launch phase accident scenarios (i.e., Command Shutdown and Destruct, Titan IV (SRMU) Fail-to-Ignite, Centaur Tank Failure/Collapse, and Inadvertent Reentry from Earth Orbit) that are deemed representative of those which could potentially result in a release of plutonium dioxide from the RTGs or RHUs. The planned Cassini Final Safety Analysis Report (FSAR) for the nuclear launch safety analysis and evaluation processes will provide more detailed evaluations of the full set of accidents and environments that could occur during the Cassini mission.

[3] Due to the preliminary nature of the analyses presented in the EIS, no uncertainty analysis was performed and uncertainties are addressed in only general terms. Uncertainty analysis will be performed as part of the ongoing studies in support of the Cassini FSAR.

of currently available supporting analyses, or that corresponding to a total release probability greater than or equal to a probability cutoff of 10^{-7}.

C. Assessment of the Analysis

Through over three decades of research, development, test, and evaluation, DOE has reduced the hazards associated with the use of the RTG space power system by the design of the RTG. Materials have been chosen (e.g., plutonium dioxide in ceramic form) and designs selected which, in the event of an accident, contain or immobilize the fuel to the maximum extent practical.

The results of the analysis show that in most launch phase accidents[4] there would be no release of nuclear material. In the event of a release, the analysis indicates that for neither the expectation case nor the maximum case would there be any health effects (i.e., excess latent cancer fatalities).

During the interplanetary portion of the mission, postulated inadvertent reentry accident scenarios could result in release of plutonium dioxide. However, the mission's design ensures that the expected probability of such reentry is less than one in one million. If such an accident were to occur, the expectation case predicts that there could be approximately 2300 health effects worldwide over a 50-year period. The EIS presents a mission risk summary (Table 4-18, page 4-78 of the EIS) in which the risks of health effects are divided by the potentially affected populations to estimate the average risk per individual. In this regard, there would be a chance of about one in three trillion for the average potentially exposed individual, in the global population, incurring a fatal cancer as a result of a fuel release from an inadvertent reentry during Earth swingby.

Finally, the risks are compared with tabulated, published risk data. The risks associated with the Cassini mission are thereby seen to be several orders of magnitude less than risks encountered and accepted elsewhere in our daily lives.

Choice of Alternatives

In view of the small risks associated with the Cassini mission, it is my intention to choose the proposed action, Alternative 1 (above, page 2), based on programmatic grounds as follows.

Alternative 1, completion of preparations for and implementation of the Cassini mission, including its launch on a Titan IV (SRMU or SRM)/Centaur in October 1997, the secondary opportunity in December 1997, or the backup opportunity in March 1999, would enable the earliest and best return of scientific information, make most effective use of fiscal, human and material resources, and avoid disruption of the Nation's program for solar system exploration.

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[4] See footnote 2 on p. 4

It is important that the Cassini mission is accomplished while the Voyager exploration results are recent and much of the associated scientific expertise is still available. There would be more than 23 years between the Voyager flybys of Saturn and the 2004 arrival of Cassini (for the primary launch opportunity). The exploration of the Saturn system by Cassini is essential to answering some fundamental questions about the origins of life and of our solar system. The international scientific and technological community anxiously awaits its results.

The no-action alternative, while presenting the minimum environmental risk, would, however, jeopardize our Country's unique Outer Solar System Exploration Program, deprive society of the invaluable scientific knowledge which will result from this mission, and could seriously disrupt and strain the international partnerships the U.S. has formed to undertake space activities for peaceful purposes, such as the Cassini mission. The choice to complete preparations for and to implement the mission is fully consistent with the mandate of the National Aeronautics and Space Act to contribute materially, among other things, to the expansion of human knowledge of phenomena in space.

D. Additional Information

In addition to requirements under the NEPA and NASA policy and procedures, there is a separate and distinct Executive Branch interagency process for evaluating the nuclear launch safety of the mission. Pursuant to paragraph 9 of Presidential Directive/National Security Council Memorandum #25 (PD/NSC-25), a Safety Evaluation Report (SER) will be prepared by an ad hoc Interagency Nuclear Safety Review Panel (INSRP). I will be fully briefed on the outcome of the safety analyses and the Cassini INSRP evaluation prior to the launch of the Cassini mission.

Extensive safety and technical reviews are continuing for the Cassini mission. In the event there are significant differences between the analysis for the EIS and the results of the final safety analyses and evaluations, those differences will be considered and a determination made as to the need for any additional NEPA documentation.

E. Mitigation

The only expected or immediate environmental impacts of the Cassini mission are the same as those for every Titan IV launch, and mitigation will accordingly be the same. This EIS primarily addressed possible radiological consequences of mission accidents. Regarding such possible radiological impacts, NASA, with expert technical assistance from DOE, the Department of Defense, the U.S. Environmental Protection Agency, and other federal agencies, and in cooperation with state and local authorities, will develop a federal radiological emergency response plan. Key elements of monitoring and data analysis equipment will be predeployed to enable rapid response in the event of a launch contingency. The plan, to be documented elsewhere, will address both monitoring and mitigation activities associated with the launch. In particular, post-accident mitigation activities, if required, will be based on detailed monitoring and assessment at that time. The plan will carefully detail the roles of the agencies involved. NASA will be the Cognizant Federal Agency coordinating the federal response for accidents occurring within U.S. jurisdiction, and would coordinate with the Department of State and other cognizant agencies, as appropriate, in the implementation of other responses.

Decision

Based upon all of the foregoing, I am confident that reasonable means to avoid or minimize environmental harm from the Cassini mission have been adopted; or, if not already adopted, will be adopted, as appropriate, upon conclusion of the safety analyses. Accordingly, it is my decision to complete preparation of the Cassini mission for launch in the October 1997 opportunity, or either the secondary or backup opportunities, and to implement the mission.

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10/20/95
Date

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